Insight from the A-Train into Global Air Quality

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OMI NO_2 Team

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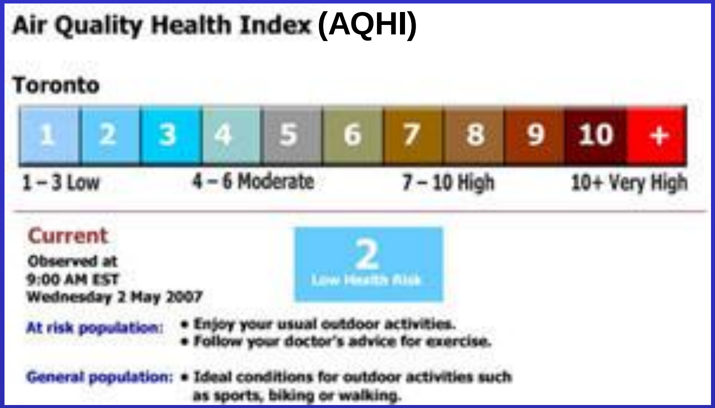
Two Applications of Satellite Observations for Air Quality

Estimating Surface Concentrations

(large regions w/o ground-based obs)



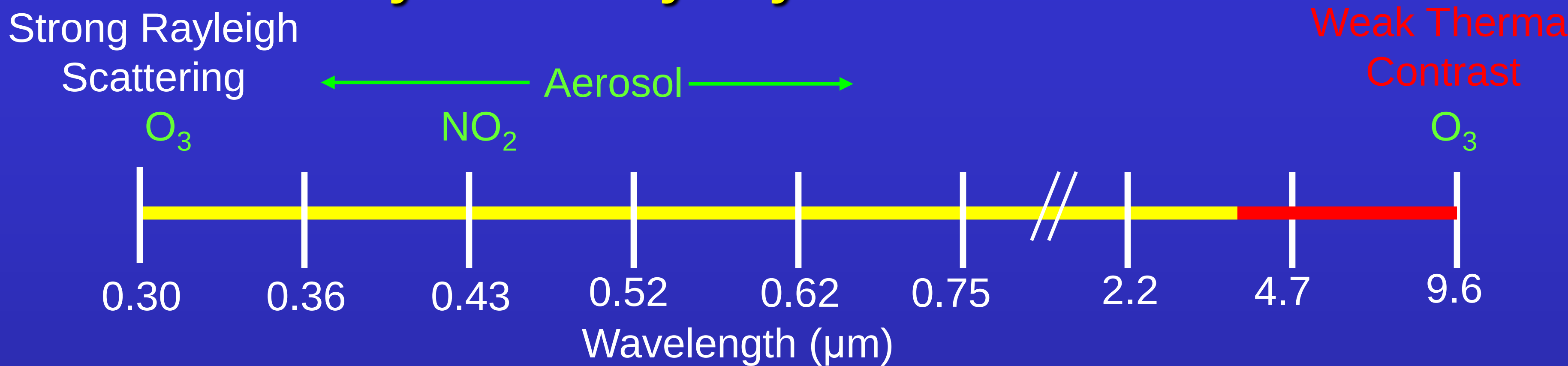
Key pollutants: $PM_{2.5}$, O_3, NO_2

$PM_{2.5}$: fine aerosol

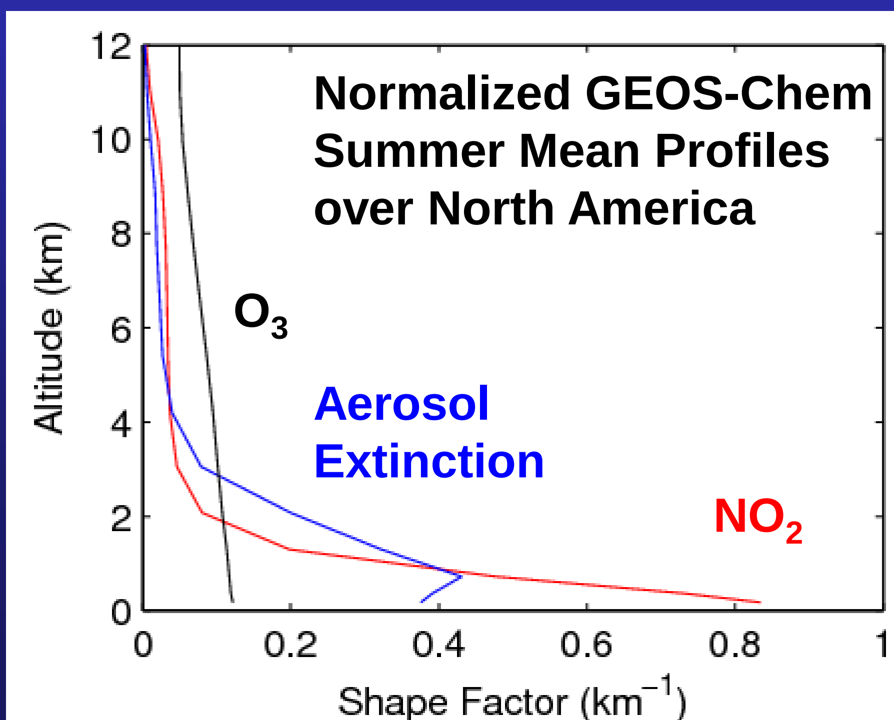
Top-down Constraints on Emissions

(to improve AQ simulations)

Column Observations of Aerosol and NO_2 Strongly Influenced by Boundary Layer Concentrations



Vertical Profile Affects Boundary-Layer Information in Satellite Obs

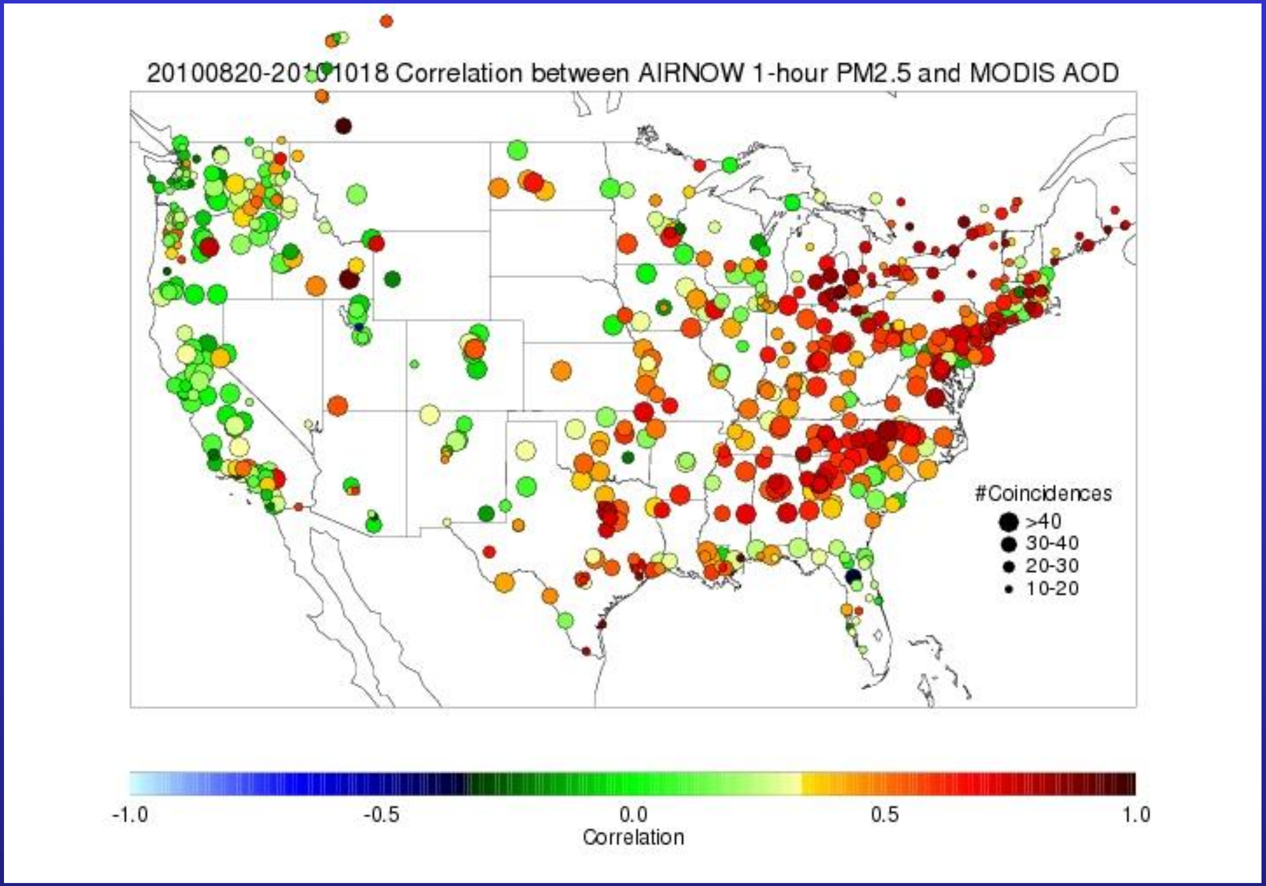


$$S(z) = \frac{C(z)}{\Omega}$$

S(z) = shape factor
C(z) = concentration
Ω = column

Martin, AE, 2008

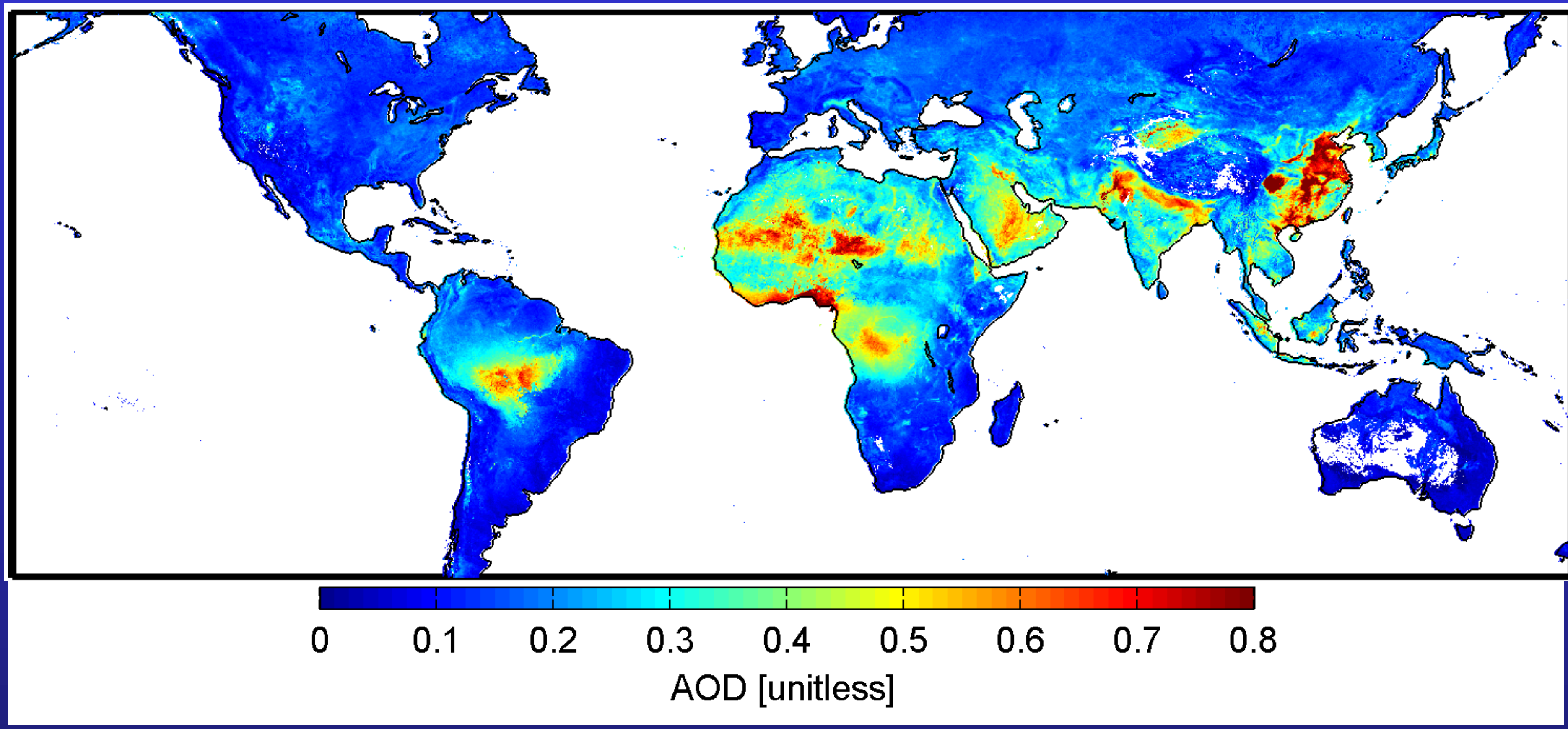
Temporal Correlation of AOD vs In Situ $PM_{2.5}$



Correlation over Aug-Oct 2010

Combined AOD from MODIS (and MISR) for 2004-2008

Rejected Retrievals over Land Types with Monthly Error vs AERONET >0.1 or 20%

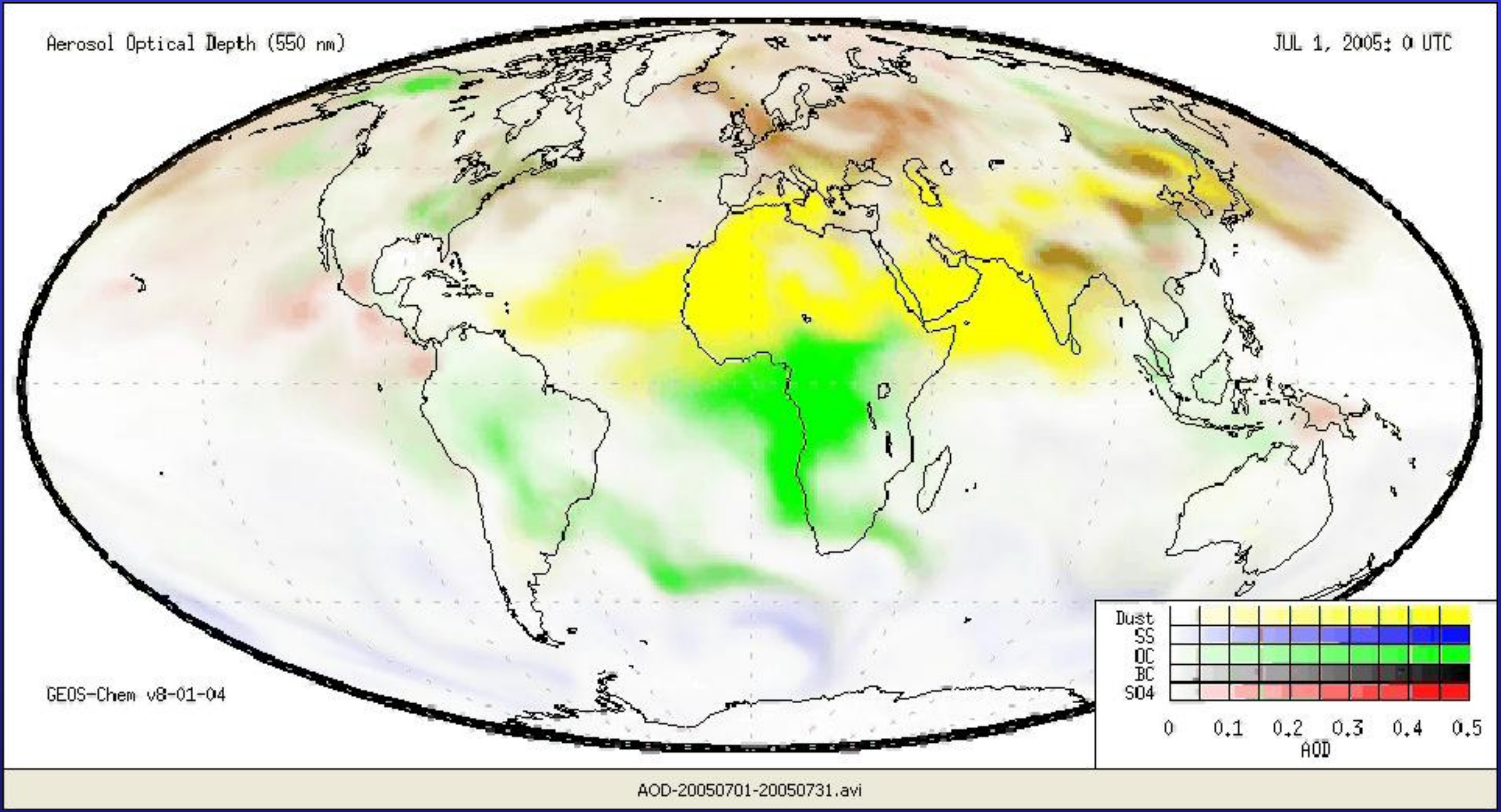


Spatial Correlation (r) of AOD vs in situ $PM_{2.5}$ for North America

MODIS:	**r = 0.39**
MISR:	**r = 0.39**
Simple Average:	**r = 0.44**
Combined:	**r = 0.61**

van Donkelaar et al., EHP, 2010

Chemical Transport Model (GEOS-Chem) Simulation of Aerosol Optical Depth



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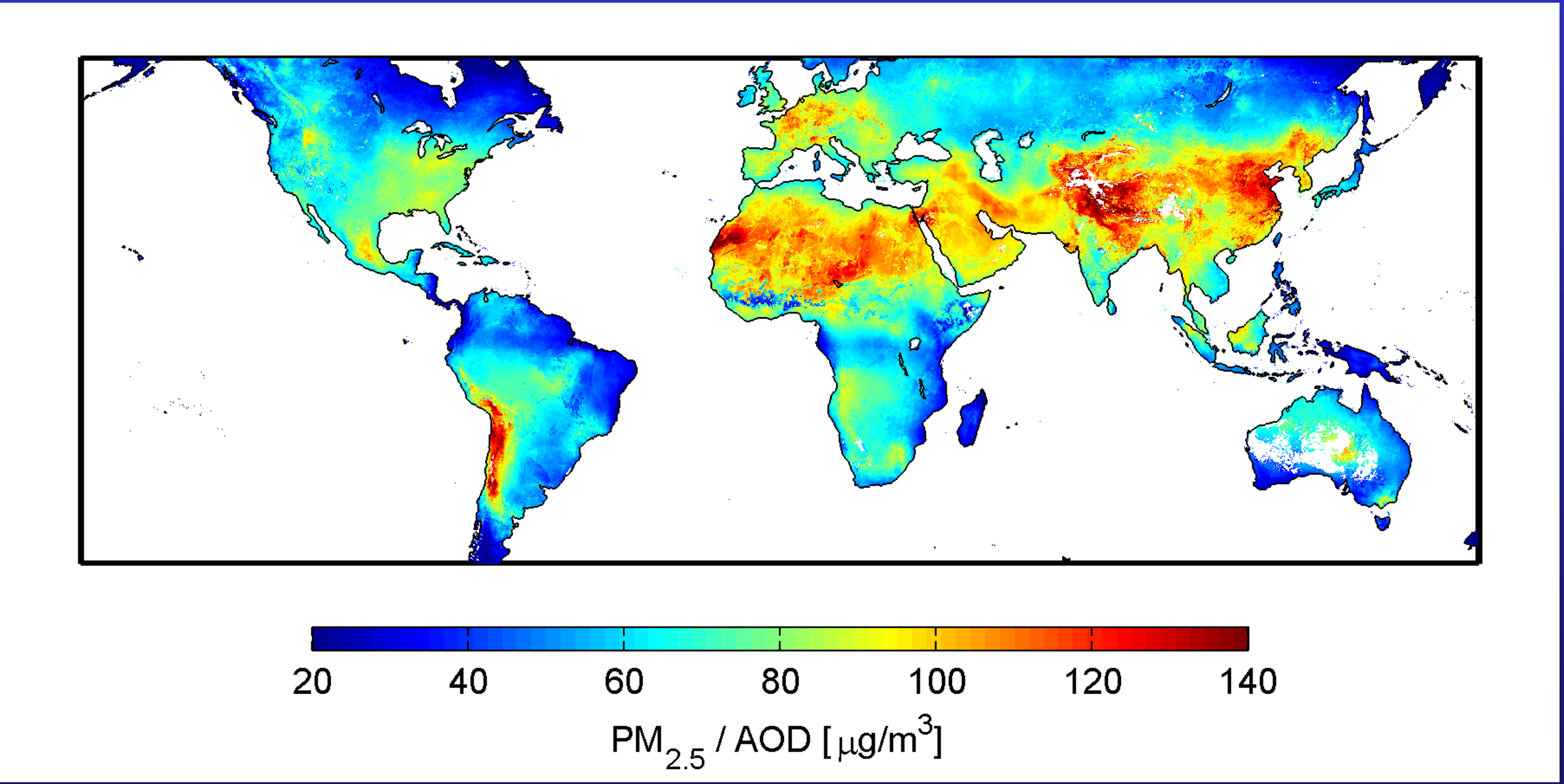
Ground-level "dry" $PM_{2.5} = \eta \cdot AOD$

η affected by vertical structure, aerosol properties, relative humidity

Obtain η from aerosol-oxidant model (GEOS-Chem) sampled coincidently with satellite obs

GEOS-Chem Simulation of η for 2004-2008

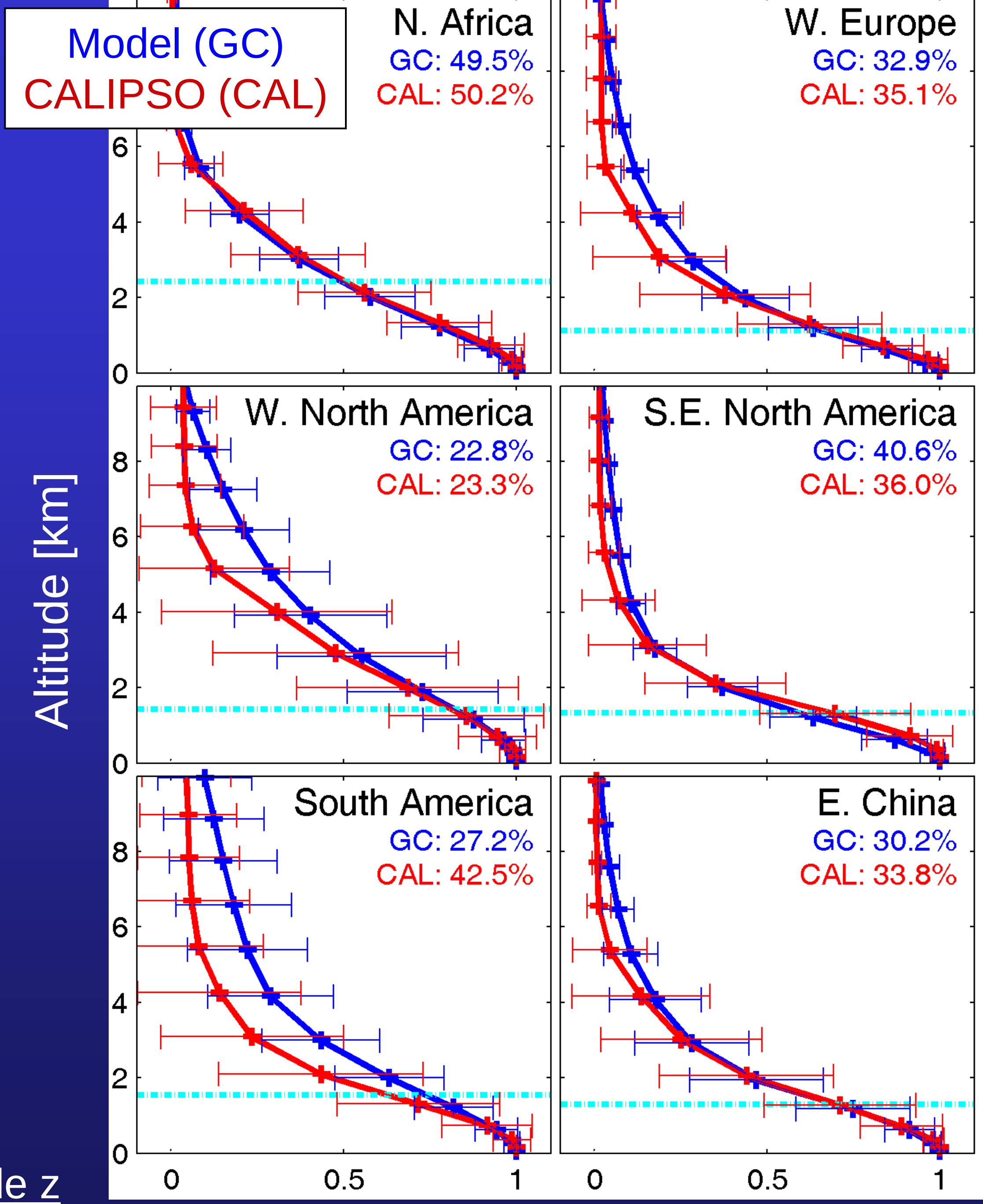


van Donkelaar et al., EHP, 2010

Evaluate GEOS-Chem Vertical Profile with CALIPSO Observations

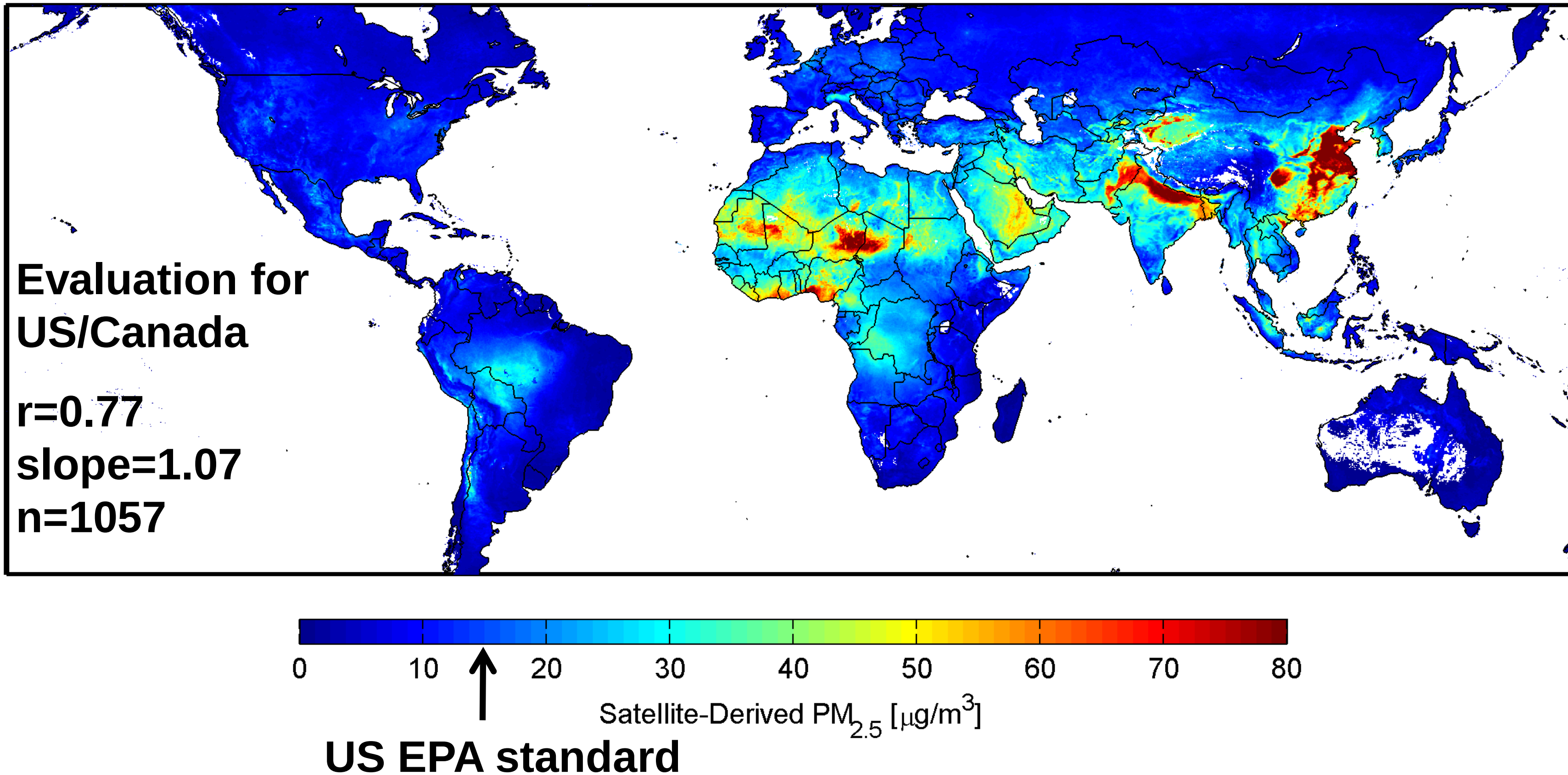
- **Coincidently sample model and CALIPSO extinction profiles**
  - **Jun-Dec 2006**
- **Compare % within boundary layer**

van Donkelaar et al., EHP, 2010



Optical depth above altitude z / Total column optical depth → $\tau(z)/\tau(z=0)$

Global Climatology (2004-2008) of $PM_{2.5}$ from MODIS (& MISR) AOD and GEOS-Chem AOD/$PM_{2.5}$ Relationship

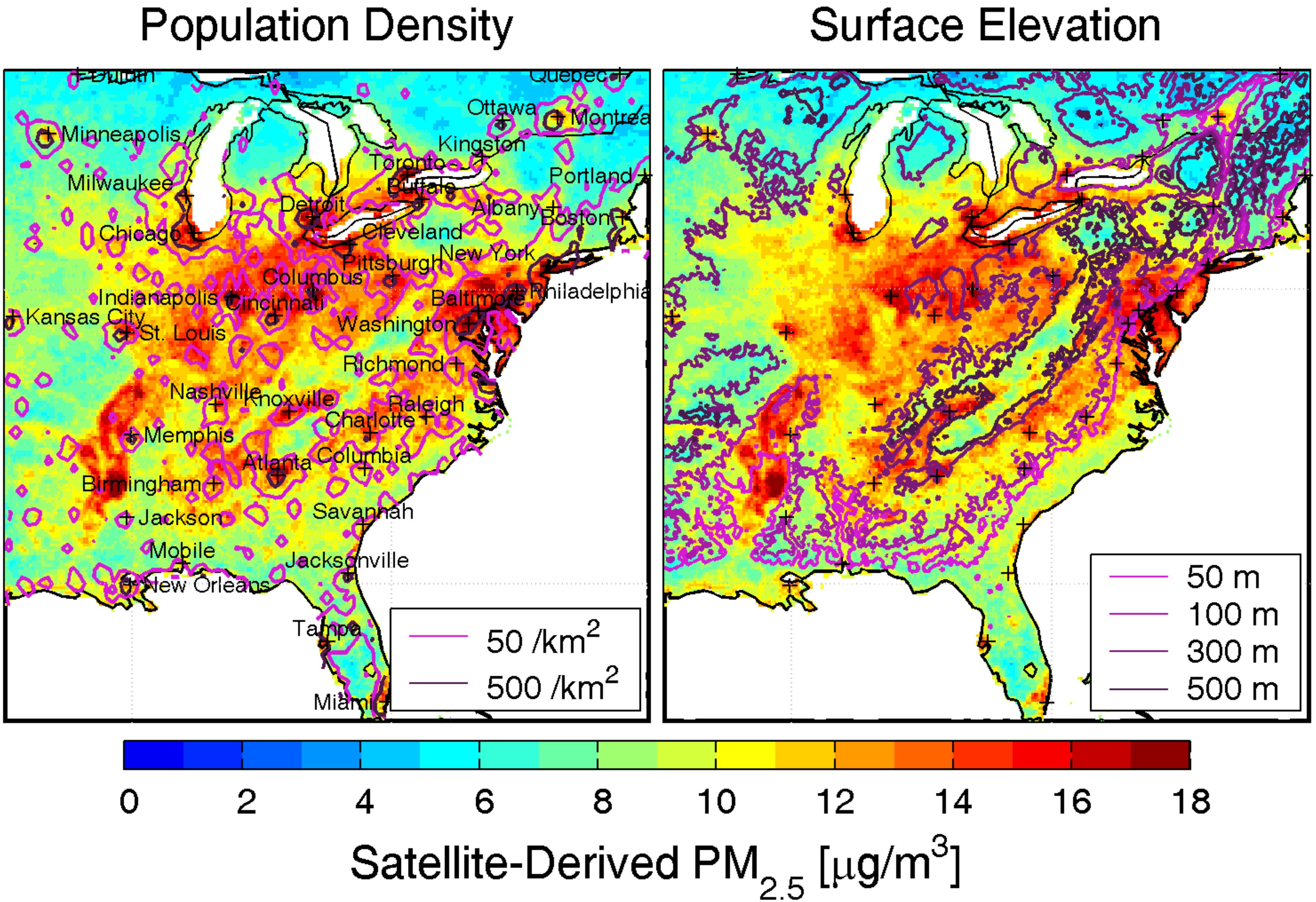


Evaluation with measurements outside Canada/US

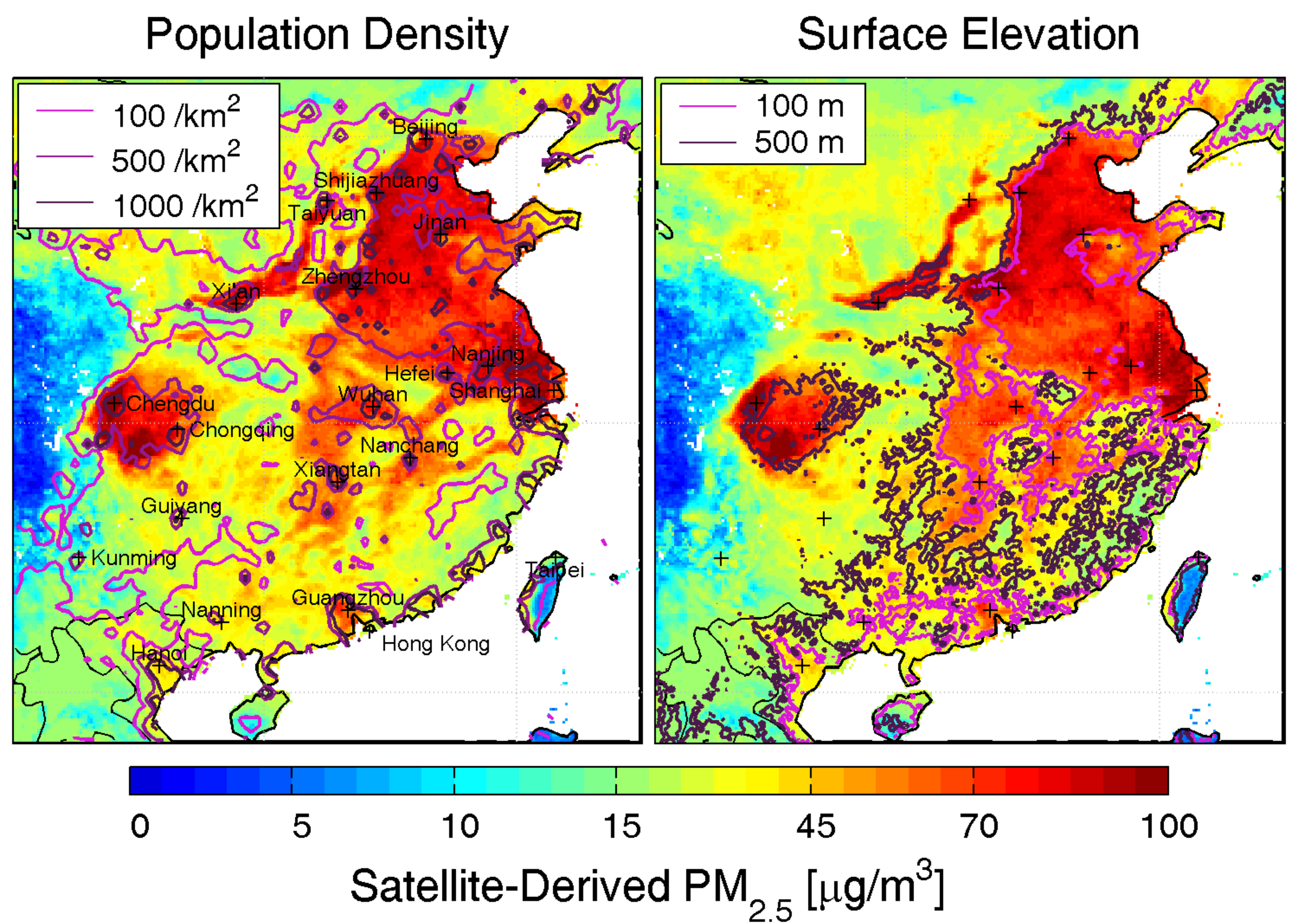
	Number sites	Correlation	Slope	Offset (ug/m^3)
Including Europe	297	0.75	0.89	0.52
Excluding Europe	107	0.76	0.96	-2.8

Better than in situ vs model (GEOS-Chem): r=0.52-0.62, slope = 0.63 – 0.71

van Donkelaar et al., EHP, 2010



van Donkelaar et al., EHP, 2010

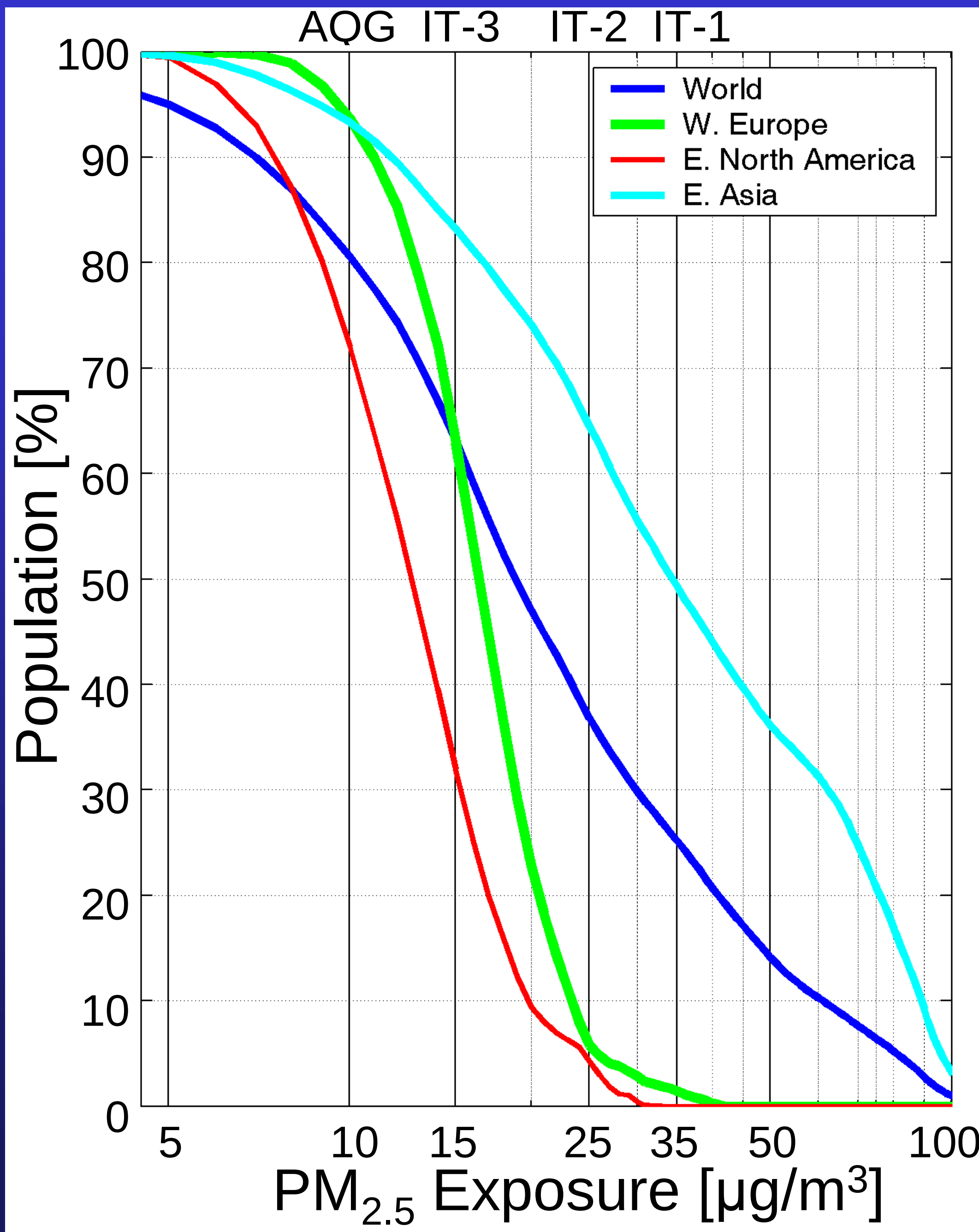


van Donkelaar et al., EHP, 2010

Data Valuable to Assess Health Effects of $PM_{2.5}$

- 80% of global population exceeds WHO guideline of 10 μg/m^3
- 35% of East Asia exposed to >50 μg/m^3 in annual mean
- 0.61±0.20 years lost per 10 μg/m^3 [*Pope et al.*, 2009]
- Estimate decreased life expectancy due to $PM_{2.5}$ exposure

WHO Guideline & Interim Targets



van Donkelaar et al., EHP, 2010

USA Today: Hundreds Dead from Heat, Smog, Wildfires in Moscow

9 Aug 2010: “Deaths in Moscow have doubled to an average of 700 people a day as the Russian capital is engulfed by poisonous smog from wildfires and a sweltering heat wave, a top health official said Monday.”

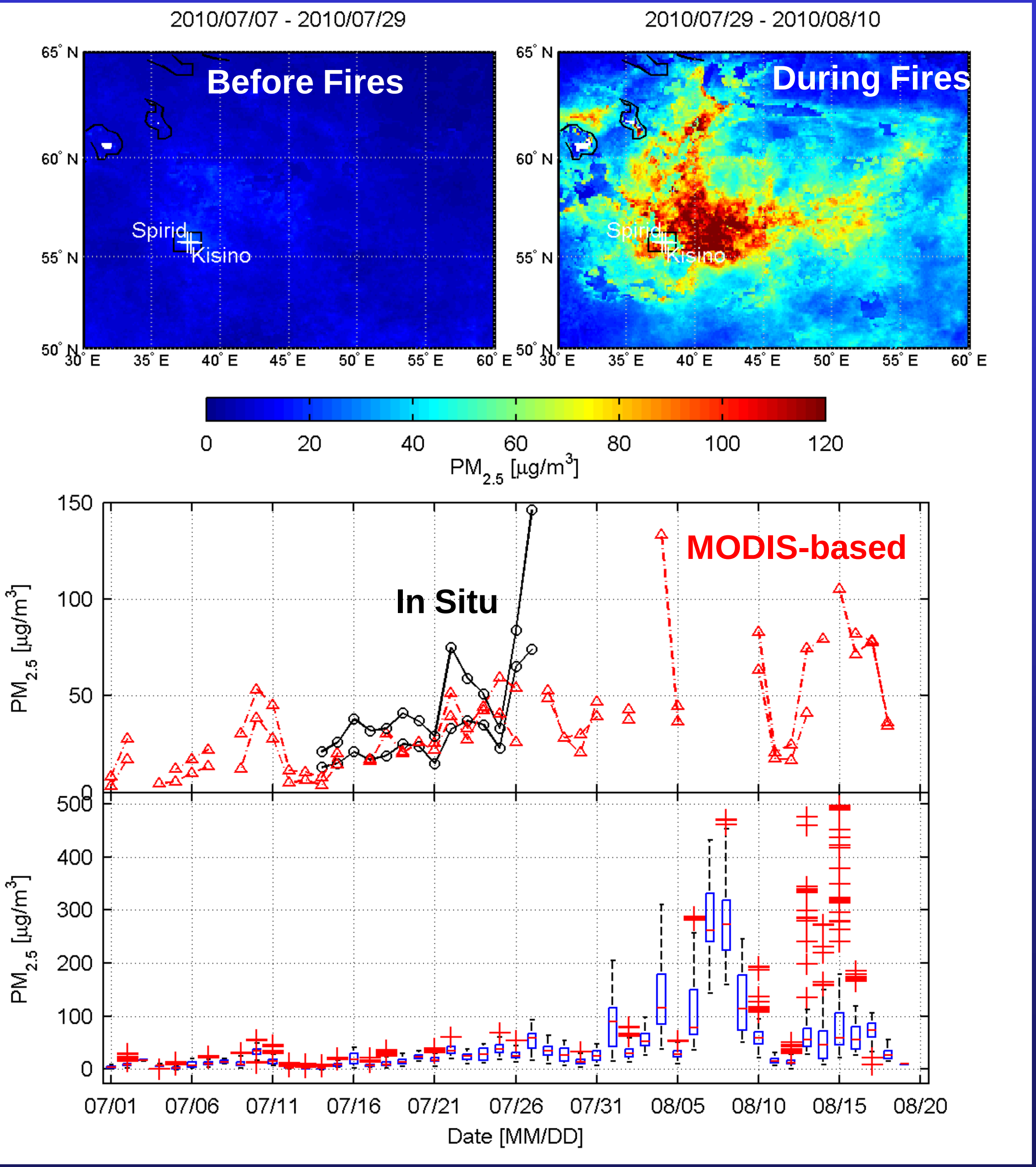
MODIS/Aqua: 7 Aug 2010

$PM_{2.5}$ Estimate from MODIS AOD and GEOS-Chem AOD/$PM_{2.5}$

Near Moscow

Evaluation Near Moscow

Regional Mean MODIS-based Estimate



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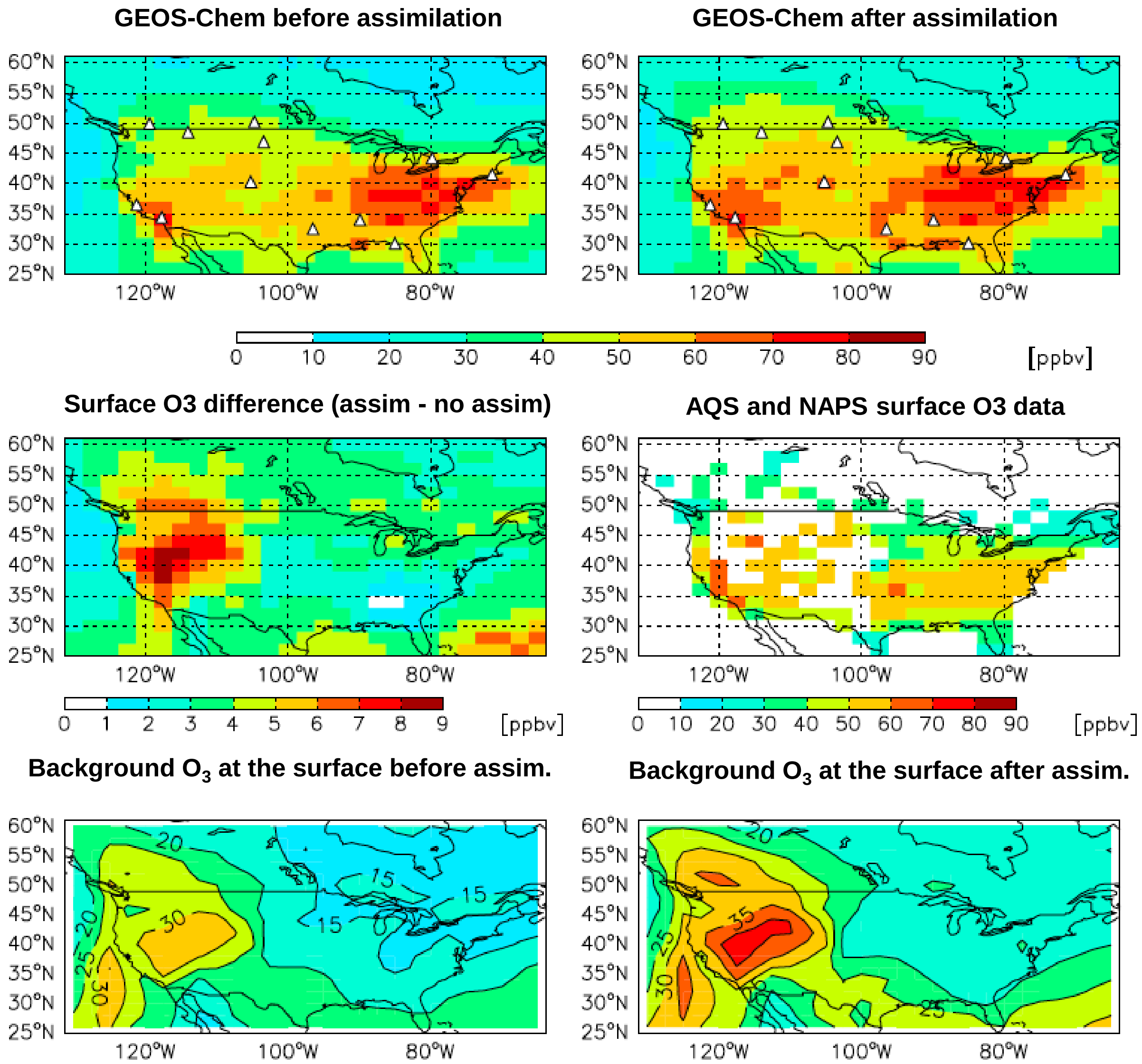
Impact of TES Assimilation on Surface Ozone (Aug. 2006)



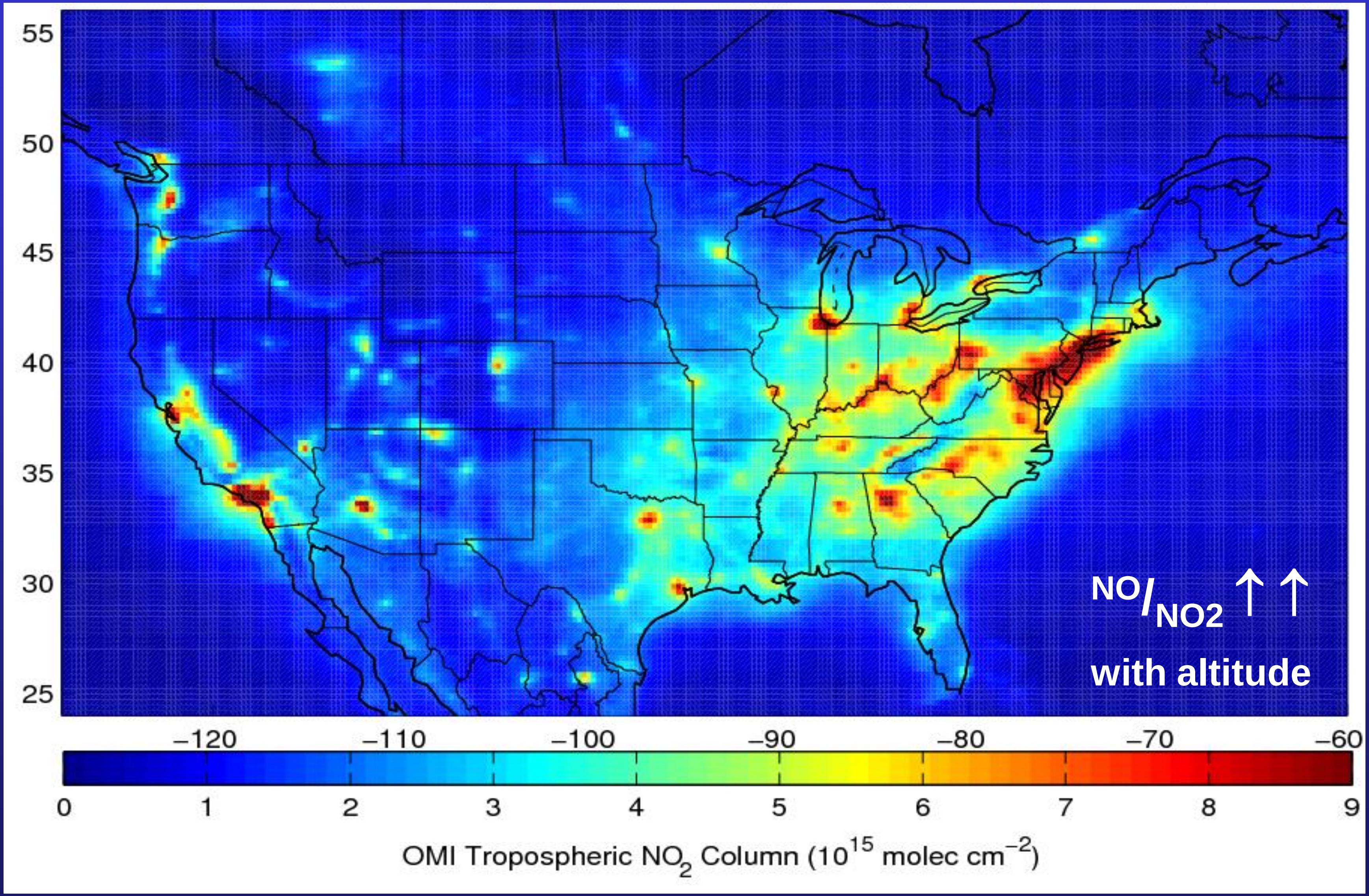
The model underestimates surface ozone in the west

Without assimilation the model underestimates background ozone by as much as 9 ppb (in western North America)

TES-based estimates of background O_3 are 20-40 ppb

[Parrington et al., GRL, 2009]

OMI Tropospheric NO_2 Column Proxy for Surface Concentration

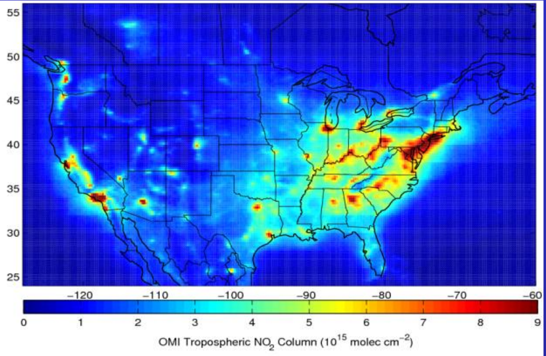


$^{NO}/_{NO2}$ ↑↑ with altitude

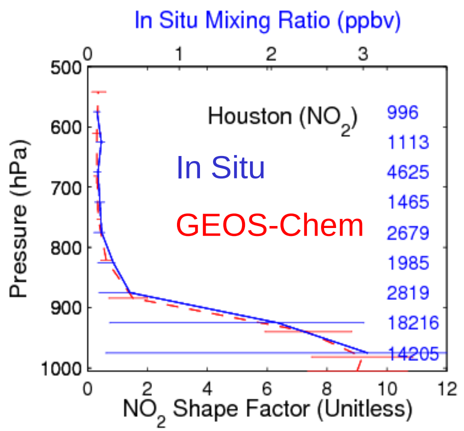
OMI Standard Product: October 2004 – September 2007 Inclusive

General Approach to Estimate Surface Concentration

Daily OMI Tropospheric Column



Coincident Model (GEOS-Chem) Profile

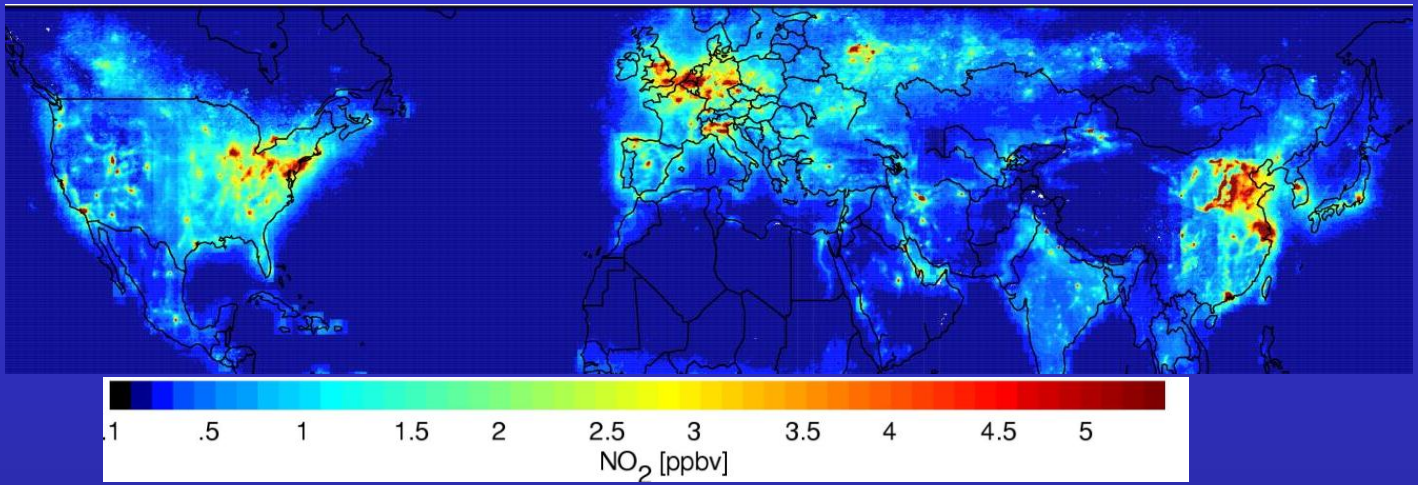


$$S_O = \Omega_O \left[\frac{S_M}{\Omega_M} \right]$$

S → Surface Concentration

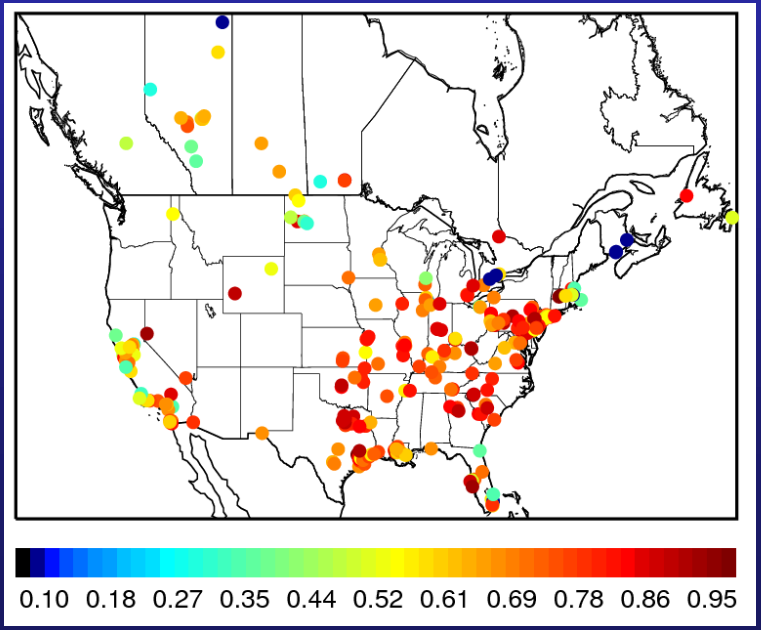
Ω → Tropospheric column

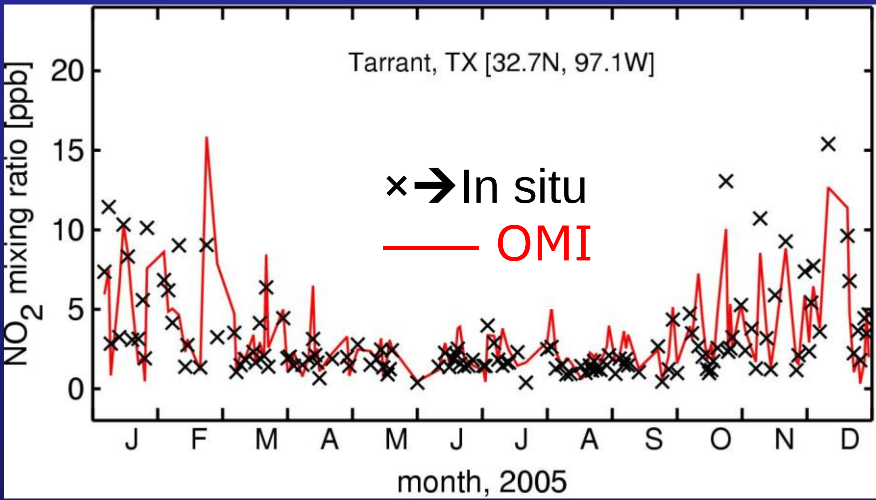
Ground-Level NO_2 Inferred From OMI for 2005



Spatial Correlation of Mean vs In Situ for North America = 0.78

Temporal Correlation with In Situ Over 2005





Lamsal et al., JGR, 2008

Application of Satellite Observations for Timely Updates to NO_x Emission Inventories

Use GEOS-Chem to Calculate Local Sensitivity of Changes in Trace Gas Column to Changes in Emissions

Fractional Change in Emissions

$$\Delta E = \beta \Delta \Omega$$

Fractional Change in Trace Gas Column

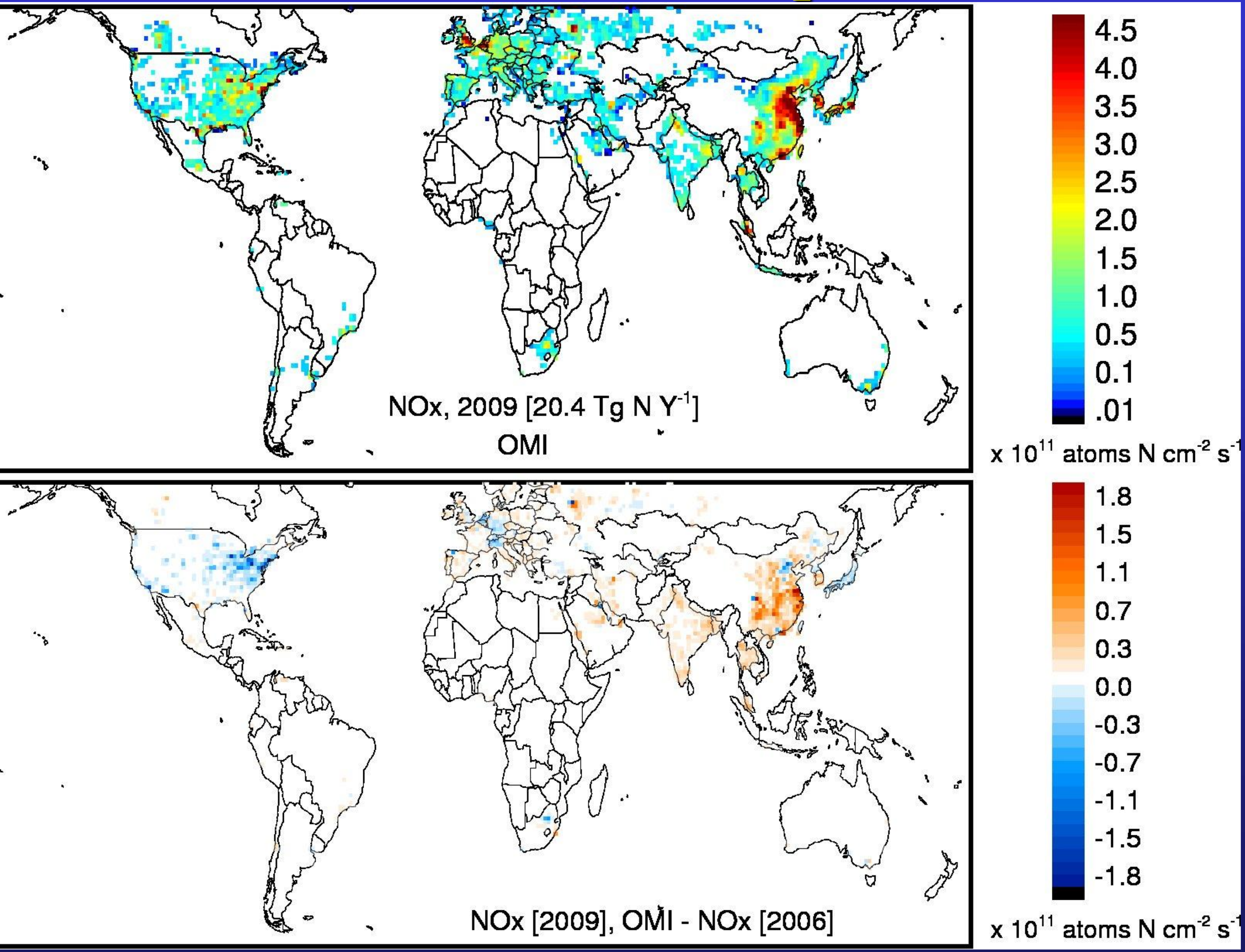
Local sensitivity of column changes to emissions changes

Apply to regions where anthropogenic emissions dominate (>50%)

Walker et al., ACP, 2010

Lamsal et al., GRL, in prep

Forecast Inventory for 2009 Based on Bottom-up for 2006 and OMI NO_2 for 2006-2009

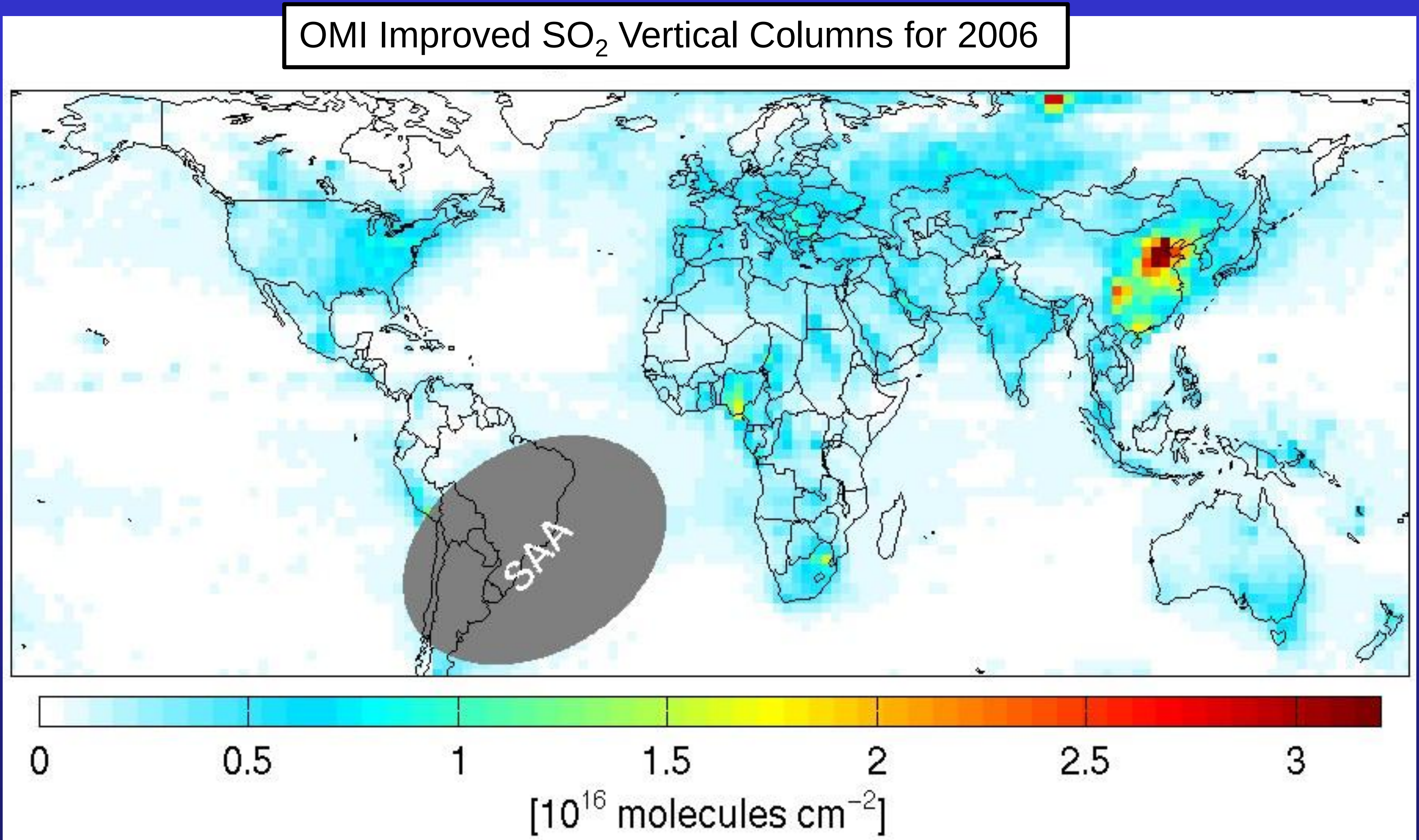


9% increase in global emissions

21% increase in Asian emissions

Lamsal et al., GRL, in prep

OMI SO_2 Column Retrievals Reflect Anthropogenic Emissions

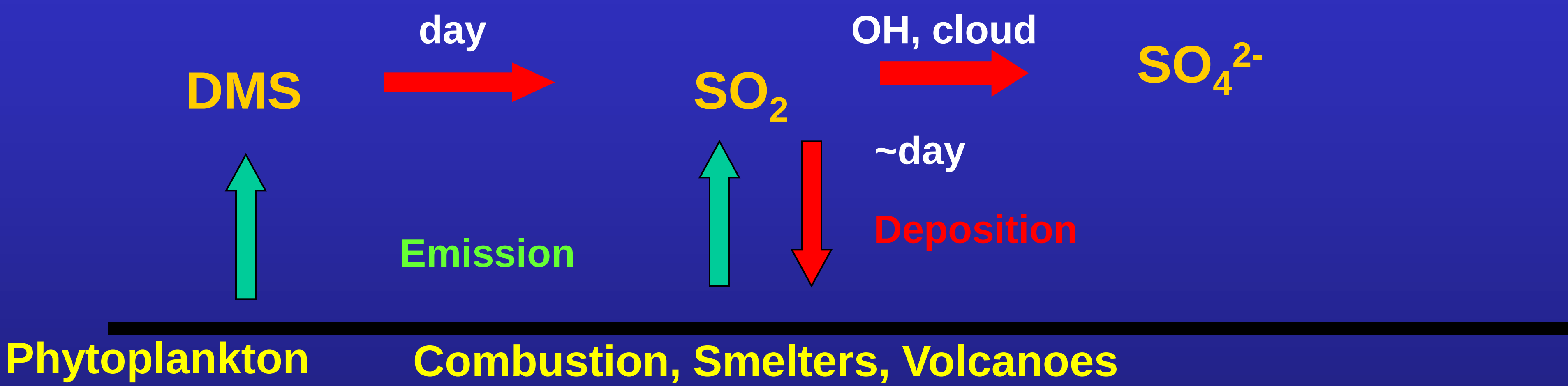


Agreement with Aircraft Observations (INTEX-B): slope = 0.95, r=0.92

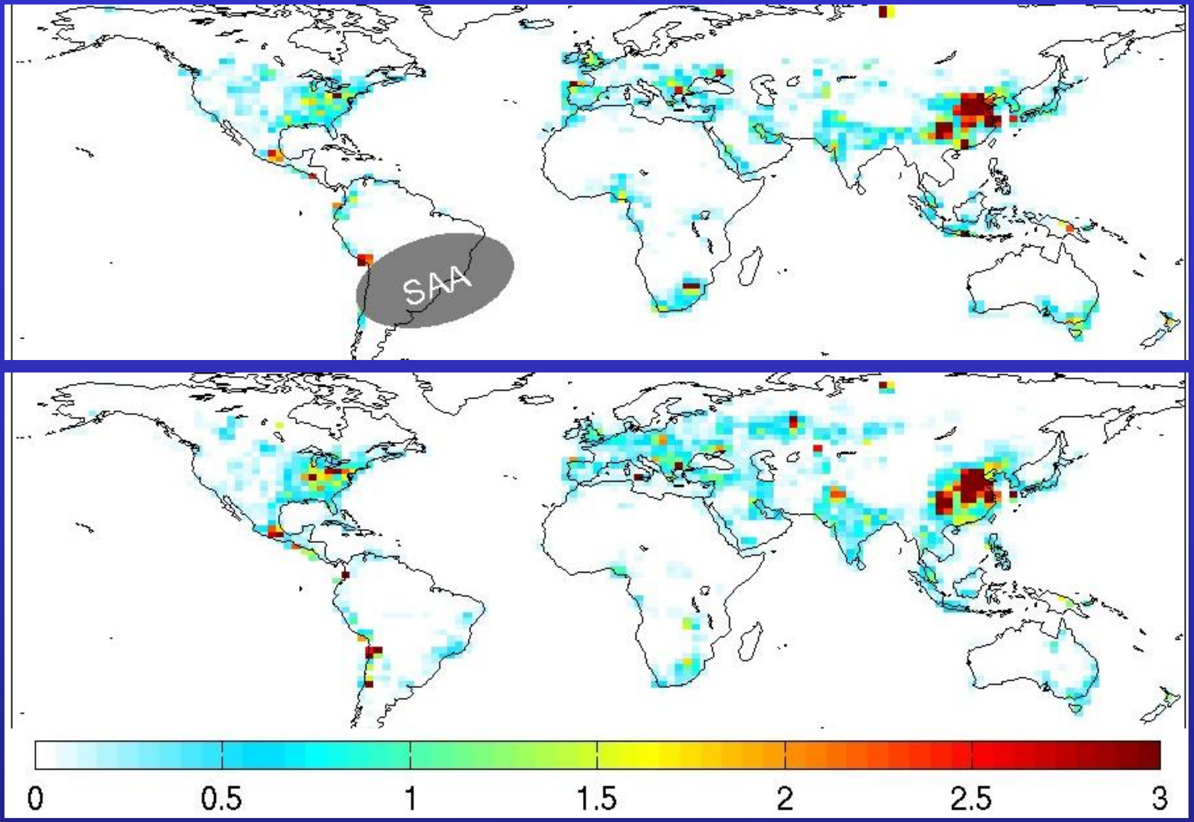
Lee et al., JGR, 2009

Use OMI SO_2 Columns to Map SO_2 Emissions
Apply GEOS-Chem for the Inversion

Tropospheric SO_2 column ~ E_{SO2} Over Land



Global Sulfur Emissions Over Land for 2006



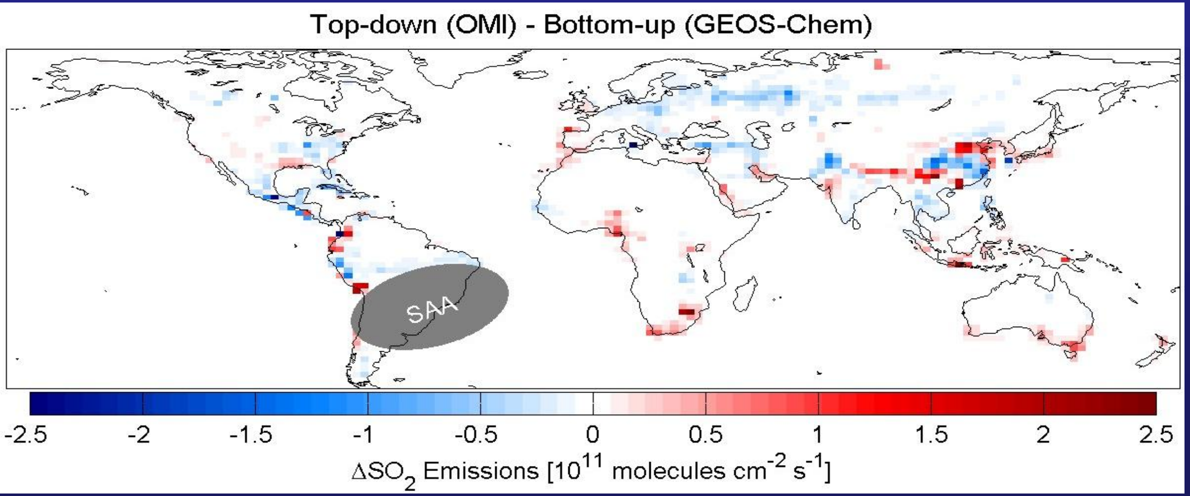
Top-Down (OMI)

49.9 Tg S/yr

r = 0.77 vs bottom-up

Bottom-Up in GEOS-Chem (EDGAR2000, NEI99, EMEP2005, Streets2006) Scaled to 2006

54.6 Tg S/yr



Top-Down Minus Bottom-up

Volcanic SO_2 Columns (>10 DU) Excluded From Inversion

Lee et al., JGR, submitted

A-Train Has Provided Unprecedented Insight Into Global Air Quality

Chemical Transport Model Plays a Critical Role in

Relating Retrieved and Desired Quantity

Challenges

- **Develop retrievals to increase boundary-layer information**
- **Continue to develop simulation to relate retrieved and desired quantity**
- **Develop comprehensive assimilation capability**

(i.e. CALIPSO vertical profiles and OMI SO_2 to inform AOD/$PM_{2.5}$ relationship)

Acknowledgements

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